MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

EOP3046 – OPTICAL WAVEGUIDE AND DEVICES

(OPE)

17 OCTOBER 2019
9:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of 7 pages with 4 Questions only.

2. Attempt **ALL FOUR** questions. The questions do not carry the same marks distribution. The marks distribution for each question is given at the end of every question.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Refer to Figure Q1(a), just before point *C*, rays 1 and 2 have opposite k_y terms in their phases as they are traveling in opposite *y*-directions. The electric fields of rays 1 and 2 at *C* are:

$$E_1(y,z,t) = E_0 \cos(\omega t - \beta_m z + \kappa_m y + \phi_m)$$
$$E_2(y,z,t) = E_0 \cos(\omega t - \beta_m z - \kappa_m y)$$

Show that the interference of these two waves create a standing wave pattern.

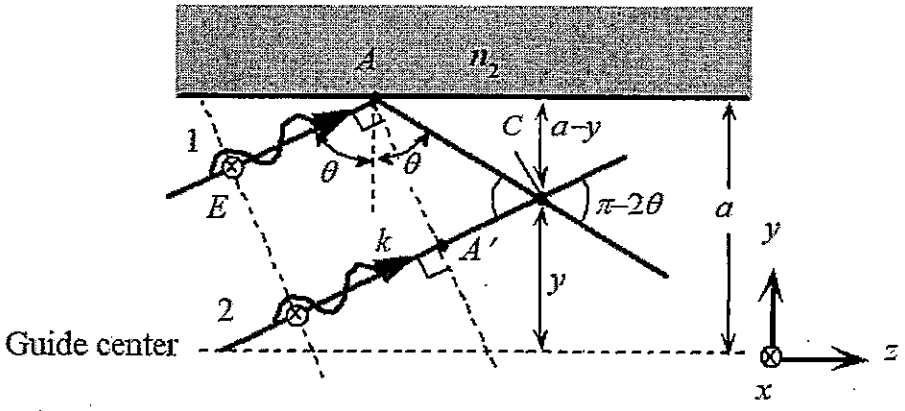

Figure Q1(a)

[7 marks]

(b) Calculate the amount of reflection and phase shift when a light ray passes through a boundary of water (n=1.33) and air (n=1) at an angle perpendicular to the boundary.

[4 marks]

(c) A manufacturer wishes to make a silica core step-index fiber with $V = 75$ and a numerical aperture NA = 0.30 to be used at 1300 nm. If $n_1 = 1.458$, what should the cladding index and the core size be?

[4 marks]

(d) With help of a sketch, describe *Mode Field Diameter* (MFD). Explain why MFD is an important parameter.

[6 marks]

Continued...

(e) Draw the electric field pattern of the first three modes of a planar waveguide in Figure Q1(e) below. Show clearly how the three modes differ in terms of shape, zero crossing and also penetration into the cladding.

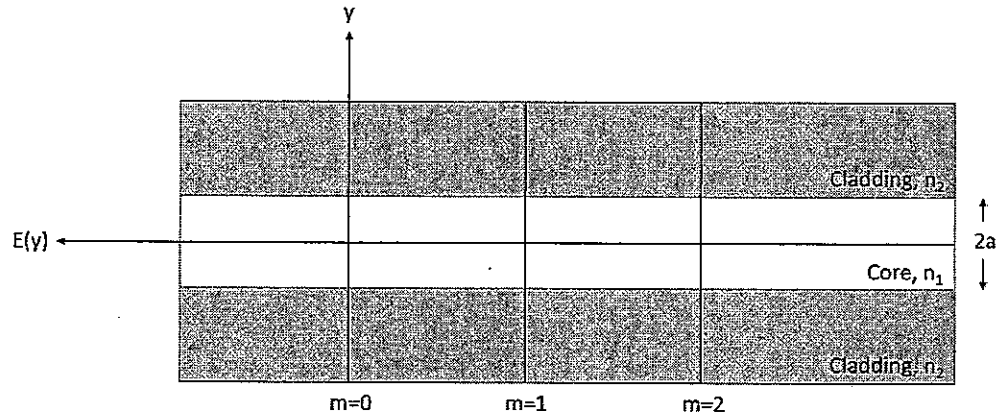

Figure Q1(e)

[4 marks]

Continued...

Question 2

(a) State FOUR (4) types of scattering losses in optical waveguides and state their class (e.g. linear or nonlinear). Describe the origin of each of the scattering.

[10 marks]

(b) Describe Polarization Mode Dispersion in terms of the origin, mechanism and how it accumulates with the length of the fiber.

[3 marks]

(c) Derive the formula for the delay difference at the end of a multimode fiber between the fastest and the slowest modes.

[7 marks]

(d) *Four Wave Mixing* (FWM) is a type of nonlinear effects. Give TWO (2) detrimental effects of FWM to signal transmission and THREE (3) ways how FWM can be reduced.

[5 marks]

Continued...

Question 3

(a) Consider a commercially available 32 x 32 single mode coupler made from a cascade of 3 dB fused fiber 2 x 2 couplers, where 5 percent of the power is lost in each element. Calculate the total loss of the 32 x 32 coupler.

[5 marks]

(b) Consider an N x N waveguide grating multiplexer having parameters as indicated in Table Q3(b) below. Calculate the path-length difference ΔL between adjacent array waveguides, and the channel spacing $\Delta\lambda$ for $m = 1$.

Parameter	Symbol	Value
Focal length	L_f	10 mm
Centre to centre spacing between the input/output waveguides	x	5 μm
Spacing between the grating array waveguides	d	5 μm
Refractive index of the grating array waveguide	n_c	1.45
Refractive index for the star coupler	n_g	1.47
Central design wavelength	λ_c	1550 nm

Table Q3(b)

[4 marks]

(c) Using a diagram, show a possible design of a fibre based *Fabry-Perot* filter. Explain the working principle of this device.

[6 marks]

(d) Using a suitable diagram, design a passive 2×2 wavelength-division multiplexer based on Mach-Zehnder interferometer.

[4 marks]

(e) Referring to Q3(d), evaluate the phase changes accumulated at both the output ports by a light signal from one of the input port, propagating through the upper and lower arms, respectively. Consider that the effective propagation constant of the waveguide is β and the length difference between the MZI arms is ΔL.

[6 marks]

Continued...

Question 4

(a) The most common material for fabricating optical waveguide is silica. This is due to its inherent properties. Give three main properties of silica that makes it suitable as a material for fabricating optical waveguides.

[3 marks]

(b) State the three stages involved in fabricating optical fibre using the single crucible method. Describe how variation on refractive index is realized, how rods are created and how the cladding is formed.

[6 marks]

(c) What are the two purposes of having a hot zone in the modified chemical vapour deposition (MCVD) process?

[4 marks]

(d) Referring to Q4(c), what makes the MCVD process has minimal contamination from atmosphere?

[2 marks]

(e) Sketch the schematic diagram (with proper labeling) of the metal deposition systems using sputtering technique.

[4 marks]

(f) Compare the performance of sputtering technique over evaporation technique in terms of material adhesion, conservation of target material composition, and control of film characteristics. Explain how it is achieved.

[6 marks]

Continued...

Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

End of paper.